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IN RE APPLICATION OF: Lennart OLSSON et al

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FOR: IMPROVEMENTS IN, OR RELATING TO SYNCHRONISATION

REQUEST FOR PRIORITY UNDER 35 U.S.C. 119
AND THE INTERNATIONAL CONVENTION

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

In the matter of the above-identified application for patent, notice is hereby given that the applicant claims as priority:

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SWEDEN	9703629-7	6 OCTOBER 1997

Certified copies of the corresponding Convention application(s) were submitted to the International Bureau in PCT Application No. **PCT/SE98/00353**.

Respectfully submitted,

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Patentansökan

~~Anmälan om uppfinning~~

1 Uppfinningens benämning

Using Adaptive Equalizer Parameters for Sampling Clock Oscillator Control in an OFDM System.

2 Beskrivning av de tekniska problem uppfinningen avser

I ett multicarriersystem av typ OFDM (inkl. DMT) är styrningen av mottagarens samplingsklocka helt avgörande för ett maximalt utnyttjande av kanalens kapacitet. Uppfinningen hämtar nödvändig information för denna styrning ur den mottagna signalen på ett nytt sätt.

3 Beskrivning av uppfinningen

I ett multicarriersystem av typ OFDM (inkl. DMT) används oftast en adaptiv kanalutjämnare som arbetar i frekvensdomänen. De interna parametrarna i en sådan utjämnare innehåller, förutom information om kanalens egenskaper, även information som kan tolkas som tidsavvikelse mellan sändarens och mottagarens samplingsklockor. Uppfinningen utnyttjar denna information för att styra mottagarens samplingsklocka på ett robustare sätt än tidigare teknik medger.

Se för övrigt bifogad beskrivning av uppfinningen (dok.nr. 5/0363-3/FCPA 109 0013).

4 I vilken produkt eller i vilket sammanhang kan uppfinningen komma att användas?

I första hand i ADSL- och VDSL-modem samt system för relativt stationära kanaler. Principen är dock allmängiltig och kan eventuellt vara användbar även i mobila och semimobila sammanhang (radiokanal).

5 På vad sätt skiljer sig uppfinningen från tidigare känd teknik?

Metoden ger ett robustare estimat av tidsavvikelsen mellan sändarens och mottagarens samplingsklockor. Detta innefattar även avvikelser på flera perioder, vilket innebär att symbolgränser också styrs till rätt läge. Robustheten erhålls genom att samtliga aktiva bärvågor används i estimeringen.

6 Om de tekniska problem uppfinningen avser har lösts genom uppfinningen, beskriv hur detta har verifierats.

Teoretisk utredning och datorsimuleringar. Implementering av metoden kommer eventuellt att göras senare inom pågående projekt.

7 Ingår uppfinningen i något pågående internt eller externt projekt?

Metoden har utvecklats inom VDSL-projektet MUSIC, som behandlar bredbandig access över kopparnät.

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Document type
Invention Description

1 (3)

Author (Subject responsible if other)	No.			
Lennart B Olsson	5/0363/3/FCPA 109 0013			
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Using Adaptive Equalizer Parameters for Sampling Clock Oscillator Control in an OFDM System

1 Abstract

A method for sampling clock oscillator control in an OFDM system, based on adaptive equalizer information, is described. The method assumes that the linear part of the equalizer parameter argument vector is related to the frame timing deviation. The estimation of the frame timing deviation is done entirely in the frequency-domain and the deviation estimate is used as a feed-back control signal for the sampling clock oscillator. The term OFDM system also includes DMT systems.

2 System environment

This method of sampling clock oscillator control is intended to work in a system described by the block diagram in Figure 1.

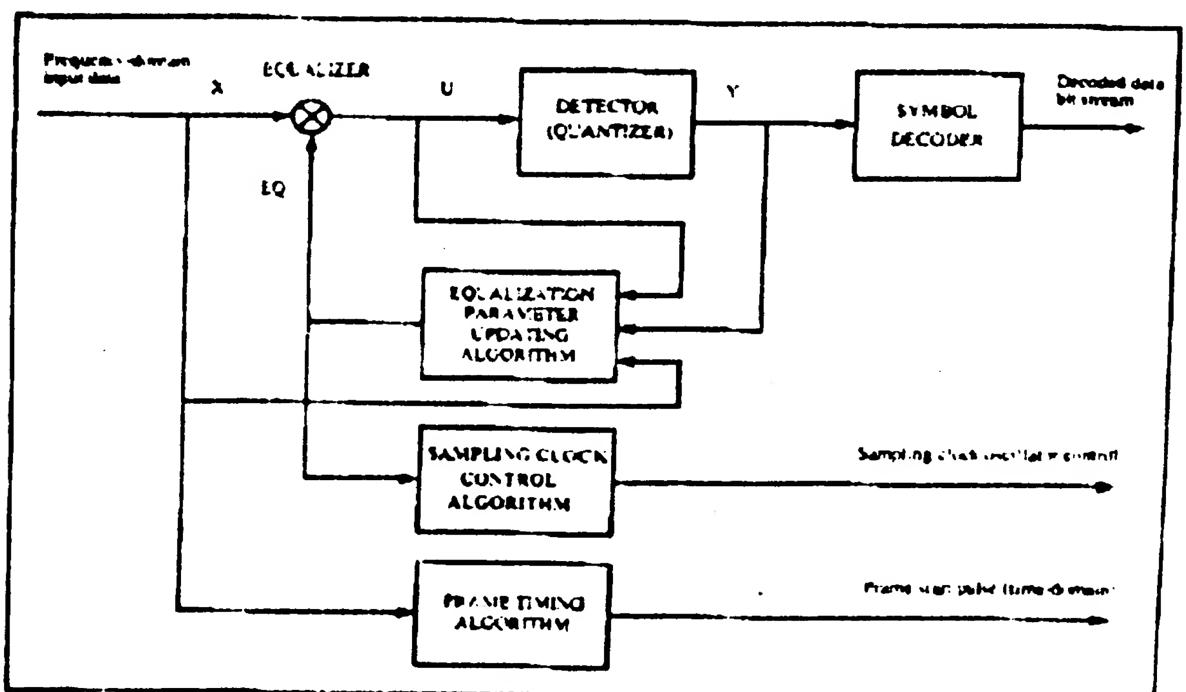

Figure 1. Equalizer and sampling control unit

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The frequency-domain data is the Fourier transformed received time-domain OFDM frames. The time-domain frames are sampled in synchronism with the transmitter so that each received frame contains data from only one transmitted frame. This is important in order to maintain the orthogonality of the frames.

Figure 2 shows a common time-domain format for the transmission of OFDM frames.

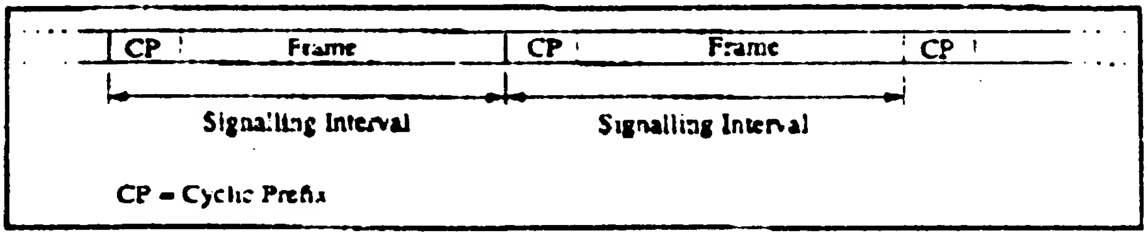

Figure 2. Time-domain OFDM data format.

The signalling interval contains a cyclic prefix and a frame. The cyclic prefix is a copy of the last part of the frame. This means that a frame sampled anywhere inside the signalling interval will contain data from one transmitted frame only. A deviation from the exact frame timing thus leads to a cyclic permutation of the frame, but the orthogonality is still maintained.

3 Frame timing deviation estimation and sampling clock control

A training procedure is necessary at start-up. The frame timing is adjusted until the received frames are sampled inside the signalling interval. The sampling clock frequency must also be adjusted to be close enough to the transmitter clock frequency, so the equalizer is able to follow the changes in the timing deviation.

The generation of frame start pulses is done by counting sampling clock intervals. Therefore, after the initial setting of this timing during the training procedure, it will be modified by the feed back control of the sampling clock oscillator.

After the training procedure the equalizer parameters *EQ* will represent the complex frequency-domain inverse of the channel. If there is a deviation from the correct timing of the time-domain sampling of the frames, there will also be a linear part of the equalizer inverse channel model argument function.

The exact linear argument function caused by the timing deviation is not available, but an approximation can be estimated using the equalizer parameters. The argument function of the equalizer parameters is generally non-linear, but a linear part can be found by taking the average slope of the argument function. This slope estimate is used as a feed-back signal to control the sampling clock oscillator frequency. The slope will converge towards zero as the sampling clock control loop settles.

The rest of the channel inverse model is taken care of by the equalizer, which continuously adapts to variations in the sample timing.

The advantage of this method is that the equalizer and the sampling control use well defined separate parts of the channel inverse model to achieve an output frequency-domain signal with zero phase deviation relative to the transmitted signal.

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4 Estimation of the unwrapped argument function linear part

The argument function of the equalizer parameters is the vector of arguments of the individual complex elements. The argument of a complex number is the inverse tangent of the imaginary part divided by the real part. A problem involved in this calculation is that the inverse tangent function is periodic with the period 2π radians. In this application it is necessary to handle larger arguments than π radians, which is the range of the inverse tangent function. An assumption used here is that the difference in argument between adjacent parameters is smaller than π radians. It is then possible to compensate for each discontinuity due to the inverse tangent function periodicity and thus unwrap the argument function.

The average slope α_k of the linear part can be calculated as shown in equation (1), or by some other standard method, using the unwrapped argument function of X_k.

$$\alpha_k = \frac{1}{N}\sum_n \frac{\angle X_{n,k}}{n} \tag{1}$$

If the lowest frequency carriers are not present in the frame, it is not possible to find the true argument function since there will be an unknown starting value of the available part of the function. This is not a problem in this application, since the slope can still be calculated.

Equation (2) shows an algorithm that gives the average slope of a contiguous band of active carriers. Indexes n_0 and n_2 are the lower and upper limits respectively of the band. Index n_1 divides the band into two equal parts. If several separate bands are used, equation (2) is applied to each band and the average of the results is calculated.

$$\alpha_k = \frac{2}{n_2 - n_0}\left(\sum_{n=n_1+1}^{n_2} \angle X_{n,k} - \sum_{n=n_0}^{n_1} \angle X_{n,k}\right) \tag{2}$$

The algorithm according to equation (2) gives a very simple hardware implementation.

5 Specific novelty of the invention

The unique innovation in this new method is the separation of the inverse channel model into one part that is sample timing dependent and another part that is not.

If the sample timing and the equalizer are controlled by separate methods they might counteract each others actions, since the equalizer is also able to take care of a time delay. This situation might eventually lead to a drift of the frame timing out of the correct interval (the cyclicly permuted interval). That can not happen when this new method is used.

The sample timing control using this new method will also be very robust in the case of disturbances, since every active carrier is used in the timing deviation estimation.

PatentKrav

1. Using Adaptive Equalizer Parameters for Sampling Clock Oscillator Control in an OFDM System characterised in the separation of the inverse channel model into one part that is sample timing dependent and another part is not.

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